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TECHNICAL EDUCATION IN RELATION TO INDUSTRIAL DEVELOPMENT.[1]

THE industrial development of the United States has created a demand for men with a technical education. The presence in the community of men with a technical education contributes to the more rapid development of our industrial enterprises. Each factor is at once a cause and a result and neither could be most effective without the other.

The history of industrial development and of industrial education are naturally inseparable. They must be treated together if one would understand their interdependence. It was never intended by the mother country that her New England colony should ever engage in manufacturing. The Earl of Chatham once said that the

> Colonists had no right to manufacture so much as a single horse shoe nail.

In 1750 a law was passed by parliament which prohibited the 'erection or continuance of any mill or other engine for slitting or rolling iron, or any plating forge to work with a tilthammer, or any furnace for making steel in the colonies under penalty of two hundred pounds.' Every such mill, engine, forge or furnace was declared a common nuisance which the governors of the province were bound to abate. The real cause of the revolution is to be found in the discontent of the colonies with such legislative oppression.

The war of the revolution, stopping all

[1] Commencement address, June 14, 1906, at the Worcester Polytechnic Institute, by Mr. Charles G. Washburn, president of the corporation.

imports from Great Britain, revived such domestic industries as had formerly existed.

Upon the return of peace in 1783, the influx of foreign goods threatened our manufacturing industries with ruin. The revolution had been successful, but had failed of its ultimate purpose. The establishment of a national government was essential to the maintenance of manufactures, the division of the powers of government among thirteen sovereign states made a uniform revenue system impossible. The manufacturers, mechanics and tradespeople wanted a federal constitution and their influence compelled its adoption by Massachusetts. The event was celebrated by processions all over the country and on one of the banners in Philadelphia was inscribed the motto:

> May the union government protect the manufacturers of America.

The first Congress justified this hope by imposing duties which should protect manufacturing enterprises, which may be considered as the result partly of the revenue laws of 1789, partly of the embargo in 1807, and of the restrictive measures and of the war of 1812 that followed. How little the idea that we should ever become a great manufacturing nation was held by our people may be gathered from correspondence between Benjamin Franklin and John Adams in 1780, in which Franklin said:

> America will not make manufactures enough for her own consumption this thousand years.

and Adams replied:

> The principal interest of America for many centuries to come will be landed and our chief occupation agriculture. Manufactures and commerce will be but secondary objects and always subservient to the other.

The feeling of skepticism in regard to the introduction of mechanical and other improvements was not confined to this country.

Admiral Sir Charles Napier fiercely opposed the introduction of steam power into the royal navy, and one day exclaimed in the House of Commons,

> Mr. Speaker, when we enter her Majesty's naval service and face the chances of war, we go prepared to be hacked in pieces by cutlasses, to be riddled with bullets, or to be blown to bits by shots and shell; but Mr. Speaker, we do not go prepared to be boiled alive.

Yet in a few years Sir Charles Napier found himself in command of the largest steam navy that the world had ever seen.

George Stephenson, the eminent engineer, spoke of the probability of steamships crossing the Atlantic. 'Good heavens! what do you say?' exclaimed Lord Stanley, rising from his seat. 'If steamships cross the Atlantic I will eat the boiler of the first boat.'

In more recent years a lord chancellor, even after he had seen a theater illuminated without candle or oil, poured ridicule on a scheme for 'supplying every house in London with gas in the same manner as they are now supplied with water by the New River Co.' Again, so eminent a chemist and gas specialist as Sir Humphry Davy himself is alleged to have said on one occasion that it was as reasonable to talk of ventilating London with windmills as of lighting it with gas.

The Academy of Sciences in France when consulted by Napoleon at the beginning of the century as to the steamboat spoke of it as a 'mad idea, a gross error, an absurdity.' When Fulton's first steamboat made the trip from New York to Albany in 1807, it happened to be the seventeenth of August, which caused many preachers to curse the machine, on the ground that seventeen was the total of the horns and the seven heads of the beast of the Apocalypse.

It was not until after 1830 that our manufactures developed, for it was not until 1835 that the construction of our

railways was vigorously commenced or that steam was availed of to any considerable extent for motive power. Meantime and from the first the cause of education had never been neglected in New England. In 1636 the general court of Massachusetts Bay, which met in September of that year, appropriated £400 towards a 'school or college,' and in 1638 John Harvard left half of his property, amounting to about £780, and all of his books, about 300 volumes, to the institution which thereafter was known as Harvard College.

For many years, indeed as late as 1850, the common school, the academies, high schools and colleges were the only instrumentalities of education in this country.

But it must not be thought that the need for a different training had not been early recognized. It was pointed out as early as 1830 that instruction in natural science could only be found in the colleges which were designed to educate those who were intended for the professional life of the ministry, the bar and medicine, and regret was expressed that no educational training had been provided for those who proposed to occupy themselves with practical affairs, and it was pointed out that those who had signalized themselves by making great inventions had been self-educated men. The inventive faculty of our people had already been at work. John Fitch, Oliver Evans and Robert Fulton had long since demonstrated that steam was to be the great motive force for land and water vehicles.

Amos Whittemore had produced the carding machine; Eli Whitney, a Worcester County boy, had invented the cotton gin. Thomas Blanchard, of Millbury, had invented, among many other ingenious and useful devices, a lathe for turning irregular shapes. Erastus Bigelow, born in West Boylston, invented, before he was fourteen, a hand loom and machine for making piping cords, and the first power loom for making counterpanes, coach lace, Brussels and Wilton carpets and wire cloth, and laid the foundation of the prosperity of the neighboring town of Clinton.

Elias Howe, of Spencer, invented the sewing machine, and Morse had invented the electric telegraph.

In view of all these and scores of other inventions, it is not surprising that the attention of thoughtful men was directed to the fact that the development of our industrial enterprises was a matter of prime importance to the prosperity of the country, and that some special training should be provided for those who were to engage in such occupations. It is true that under the patronage of our colleges, scientific schools had been established through the generosity of private individuals. Abbot Lawrence, of Boston, founded the Lawrence Scientific School of Cambridge in 1848. Joseph E. Sheffield, of New Haven, endowed the Sheffield Scientific School of Yale in 1847, and Abiel Chandler, of Walpole, N. H., endowed a separate department of technology at Dartmouth in 1852. These schools, however, all taught pure science. It was left for the polytechnic school as later developed to teach applied science. Such, in a general way, were the conditions in 1860.

July 2, 1862, Congress passed a bill granting to each state 30,000 acres of land for each senator and representative in Congress for the purpose of endowing institutions for teaching such branches of learning as are related to agriculture and the mechanic arts, and this, too, at a time when the failure of the peninsular campaign against Richmond had left the people of the country in a state of deep depression. This gave a great impetus to the cause of technical education.

The Massachusetts Institute of Technology was opened to students in 1865.

The foundation of our own school came about in this way. In the year 1865 John Boynton, of Templeton, in this state and county, placed in the hands of his former partner, David Whitcomb, of Worcester, the sum of one hundred thousand dollars for the endowment of a free school, which was to be located in Worcester if the citizens of Worcester should provide the land and suitable buildings. This condition was complied with by a gift of the land and of $61,111 contributed by two hundred and thirty-two individual names and from twenty shops and factories. The institute was incorporated May 9, 1865, under the descriptive and perhaps prolix title of Worcester County Free Institute of Industrial Science, which was changed in 1887 to the name which the institute now bears.

December 2, 1865, Ichabod Washburn, of Worcester, offered to establish a machine shop as one of the departments of instruction of the institute.

The selection of the location of the school was an appropriate one. Worcester, then a city of 30,000, had long been famed for her industries and for the intelligence and public spirit of her citizens. Her industrial growth had taken place since 1830, prior to which time her manufactures had been of the most primitive sort. The Rev. Edward Everett Hale, whose life work, happily not yet concluded, has been so productive of good to his fellow-men, told me that Judge Merrick, a resident of Worcester, once met Samuel Slater, the pioneer cotton manufacturer, on the street in Worcester. Judge Merrick said to Mr. Slater:

> We shall never be a manufacturing town in Worcester because we have so little water power.

Mr. Slater said in reply:

> Judge Merrick, you may live to see the time when Worcester will need all the water of Mill Brook to provide the steam for her steam engines.

This conversation must have occurred at some time prior to 1835 and perhaps about 1830.

It is difficult to realize that William A. Wheeler, of Worcester, who is credited with having installed in 1825 the first steam engine in the state west of Boston, should have discarded it and used horse power until 1840, when he put in another engine. William T. Merrifield at the same time put in an engine of from four to six horse power. These were probably the first efficient steam engines in Worcester.

An indication that this was congenial soil in which to plant an institution like ours is found in the formation of the Mechanics' Association, first attempted in 1819, and successful in 1841. The object of the association was:

> The moral, intellectual and social improvement of its members, the perfection of the mechanic arts, and the pecuniary assistance of the needy.

Another object was the holding of an annual fair for the exhibition of the mechanical products of the city, and the first fair was held in September, 1848.

In July, 1854, in commenting upon the association and its work, the statement was made that:

> Notwithstanding the inadequate supply of water power which is everywhere deemed so essential for the successful development of the mechanic arts, without the aid of a single act of incorporation, mechanical business has increased in this city by individual enterprise alone more than tenfold.
>
> The mechanics as a class are more enlightened than formerly, their course is onward and upward; they are not only increased in numbers, but continually expanding in influence and usefulness.

Ichabod Washburn was very much interested in this association, and eight or ten years before the founding of the institute had discussed with the Rev. Dr. Sweetser the feasibility of establishing a school in connection with the Mechanics' Association for giving scientific instruction to mechanics in the fundamental principles of me-

chanics and chemistry. It was expected that funds for the enterprise would be contributed by the prosperous mechanics and manufacturers of Worcester. The financial panic of 1857 prevented the execution of this plan, and Mr. Washburn later decided to carry out his earlier conceived purpose in connection with the institute.

Fortunate, thus in its foundation and its location, the institute began its life under the happiest auspices. In one particular its scheme for education was unique in combining with the studies ordinarily pursued in technical schools, manual labor in a shop, run upon a commercial scale and producing articles to be sold in the market.

Unsuccessful experiments in thus combining the practical with the theoretical had previously been made in Germany and Austria.

At this point I am led to inquire just what sort of a school this was in 1865, and what its founders expected of it. I understand that in the definition of the present day a trade school aims to give the pupil a thorough, practical knowledge of some handicraft. In the manual training school instruction is given in various kinds of work with tools for educational discipline. In the technical or engineering school the sciences are taught in their practical application to the various industries.

Mr. Boynton, in his letter of gift which was prepared under the advice of the Rev. Seth Sweetser, of Worcester, and Judge Emory Washburn, of Cambridge, adopted in most comprehensive form the curriculum of the scientific school as then known, with the addition of some subjects not ordinarily included.

Mr. Washburn's final letter of gift and instruction, dated March 6, 1866, discloses a purpose to establish a trade school as we now understand it, excepting that in addition to learning a trade the apprentice was to be instructed in the principles of science.

Dr. Charles O. Thompson, the first president of the faculty, of brilliant accomplishments and magnetic personality, in his inaugural address delivered at the institute November 11, 1868, said, among other things:

> Add to these considerations the fact that boys whose faculties are kept constantly alert by the training of the school are in a condition to learn faster than others the practical application of science and that the time spent in the shop will serve the double purpose of instruction and physical exercises and it will be admitted that this form of a manual labor school is at least an experiment worth trying.

The late Senator George F. Hoar, one of the charter members of the board of trustees, always untiring in his efforts in behalf of the institute, and whose memory should always be held in most grateful remembrance by us, in addressing a committee of the Massachusetts Legislature, February 11, 1869, urging an appropriation of $50,-000, said, among other things:

> You can not find an instance of a boy who has been educated in the Scientific School at Harvard College going back to the bench of the workman or the farm, and so of the Institute of Technology. Theirs will be a different, and in many particulars a higher education than ours. * * * You will not find there any boys who, having studied for two or three years, are going back to work in the shop * * * and there they will work their way up from the journeyman to the foreman and then the master mechanic.

All this testimony leads, I think, to the conclusion that the institute in 1865 was what would now be considered a combination of a scientific school and a trade school, and of a grade not as high in some respects as either the Scientific School at Harvard or the Institute of Technology in Boston.

It was frankly admitted that it was an experiment, and attention was called at the time to the fact that at Berlin the workshop connected with the school had been tried and abandoned twice. But the experiment

succeeded here, and the combination has now taken the permanent form of an engineering school of the first rank, peculiar in this respect, in which we believe it to be superior to all others, that the practise not only illustrates the scientific principles taught in the school, but also gives the students considerable experience in the use of tools and a practical knowledge of the workings of a commercial shop.

Since the founding of the institute, technical schools have been springing into existence with great rapidity in response to a constantly increasing demand for trained engineers. In speaking of this fact, President Eliot said in 1905:

> It is also true that separate schools have been set up in many parts of the country to train young men for the technical and scientific professions, but in time these schools are likely to be transferred to neighboring universities or to content themselves with training men for the lower grades of these professions, the universities all over the country being sure to appropriate the training of young men for the higher walks of the scientific professions and of business. * * * It is obvious that the policy of the American universities now under consideration has had, and is going to have, a strong effect to uplift the relatively new professions, like those of engineering, applied chemistry, architecture, music, mining, forestry, the public service and large scale manufacturing. These are highly intellectual occupations not yet universally recognized as on a level with divinity, law and medicine. The American universities will in a few generations put them all in their higher grades absolutely on a level with the older callings.

This is an interesting prophecy, but so far as it relates to the absorption of existing independent technical schools by the universities is not likely to be immediately fulfilled.

That the Worcester Polytechnic should have developed into an engineering school is a cause of great satisfaction. Progress and growth characterize all successful educational institutions. Listen to this statement:

> After God had carried us safe to New England and we had builded our houses, provided necessaries for our livelihood, reared convenient places for God's worship and settled the civil government, one of the next things we longed for and looked after was to advance learning and perpetuate it to posterity, dreading to leave an illiterate ministry to the churches when the present ministers shall be in the dust.

Such was the modest purpose of the founders of Harvard College. If the founders of this school should have the power to see us, as perhaps they have, how small their surprise compared with that of the fathers who behold Harvard University with an endowment of $18,000,000, and a student body of 4,000 being trained for most of the occupations, professional and industrial, necessary to the progress and prosperity of the nation. Contrast the first graduating class of seven with the last commencement, when 1,073 degrees were conferred. Compare the sphere of usefulness of the first president of Harvard with that of the distinguished educator who now occupies that position and who is sought to take part in the discussion of the rights of capital and labor, the proper management of corporations and kindred practical questions, to the great profit of his countrymen.

During a period of thirty years there has been a steady development in all of the departments of the institute, and the enlargement and the enrichment of the various courses has kept pace with rapidly increasing demands.

In the field of mechanical engineering this development has usually been in response to some special requirement.

The demands for power for the generation of electricity and for marine work have led to the present efficient and well-developed high-pressure steam boilers and engines, together with all the auxiliary power-house apparatus. This has also resulted in the perfecting of the steam turbine for commercial purposes, while cheap-

er power has been provided by the gas engines and producers, and, with the aid of electrical transmission, water power is also the basis of great power plants. Large wheels, higher speeds, better regulation and more efficient results are some of the new requirements which are being met in hydraulic work.

The problems in connection with the handling and transportation of materials have made great demands on the mechanical engineer and have resulted in improved hoisting machinery, conveyors, cranes, elevators, larger and more efficient locomotives and cars.

On the manufacturing side the demands have been fully as great, competition requiring more rapid and economical methods of production. These have been met by better and more powerful machine tools, automatic machinery, jigs and interchangeable parts, and within the last few years the introduction of high-speed steels for rapid work and surface grinding. Rolling-mill machinery has kept pace with the requirements for structural steel, while the response to the calls for strong and light parts for the bicycle and automobile has made possible the present perfection of these machines. The rapid development of machine molding in the foundry has come from the demand for cheaper and better castings. The further reduction of factory costs has led to the study of shop management, where every movement of worker and material is considered with an idea of reducing the cost of production.

While there have been no startling discoveries along mechanical engineering lines, there has been a continual evolution toward greater and more efficient production of power and of commercial products.

As illustrations of practical results attained may be mentioned the fact that an indicated horse-power can be produced to-day with one third the coal consumption of thirty years ago.

While in the important art of wire rod rolling, in the development of which the oldest and a most highly respected member of our board of trustees and graduates from this school have had a very conspicuous part, the tonnage output has been increased twentyfold and the cost per ton for rolling has been greatly reduced. In the year in which the first board of trustees was organized, wire manufacturers in Worcester were importing Swedish iron billets which were rolled in South Boston at a cost of $1 per 100 pounds. To-day steel billets can be rolled for 12½ cents per 100 pounds.

In the department of civil engineering the training in 1870 was confined to pure mathematics, surveying and a very limited application of theory to practise; what would now be regarded as rudimentary.

To-day the student must receive a thorough training in mathematics, physics, theoretic and applied mechanics; he must be well grounded in the elements of chemistry; and familiar with all the principles of bridge construction, and the framing of great buildings; he must possess intimate knowledge of materials, stone, brick, cements, mortars, concrete and reinforced concrete; he must know what has been done and is being done in actual construction in the several lines of his profession. And that he may be fitted to eventually direct large undertakings, he must be familiar with the principles of power development and transmission in all its modern forms.

The work of the civil engineer of to-day consists largely in the design, construction and maintenance of fixed structures. Streets, bridges, water supply systems, sewers, conduits, subways, elevated tramways, docks and wharfs in our cities; embankments, deep cuts, bridging, tunnels and

terminals for the railroad systems; dams, reservoirs, canals, penstocks, powerhouses for the great hydraulic developments, and for the reclaiming of the arid lands; ship canals, locks and dry docks for shipping; steel frames, foundations for the modern skyscraper; these are some of the subjects which occupy the attention of the civil engineer to-day.

The magnitude of these works, their cost, and the rapidity with which they must be designed and built, have enormously increased in the past thirty years. A more exact knowledge of the properties of all kinds of structural material and of the laws which govern the forces of nature, with which the engineer must work, are demanded for the economical treatment of these large projects. The percentage of error and the factor of ignorance must be reduced to the lowest terms.

In physics many important discoveries have been made. Prominent among them has been the establishment of the theory that light consists of electric and magnetic vibrations.

The discovery of electromagnetic waves which led to the invention of wireless telegraphy, by which means within a few weeks a message has been sent across the ocean.

Discoveries regarding the connection between the all-pervading ether and matter.

The discovery of the peculiarities of the discharge of electricity through gases which led to the discovery of X-rays.

The liquefaction of air and gases which led to discoveries regarding the properties of bodies at very low temperatures.

The discovery of radium and other radioactive bodies and the investigation of their properties which has produced profound changes in our views regarding the construction of matter.

Discoveries of the process of conduction of electricity through gases, liquids and solids.

Developments in electrical engineering have been almost spectacular in their number and importance, revolutionizing, as they have, means of transportation and for the transmission of speech and power, and for lighting.

The telephone in 1876. The incandescent lamp in 1879. The commercial development of dynamo machinery and electric motors. The commercial application of electricity to street railway work, which had its beginning less than twenty years ago. The transmission of power over great distances made possible by the development of the alternating current transformer. A catalogue of discoveries and inventions in this field is not necessary, as one sees them on every hand. It may be truthfully said that the department of electrical engineering has been created within a comparatively few years. It was not until 1896 that our department of electrical engineering was separated from the department of physics within which it had its beginning. Now it is one of our great departments, attracting large numbers of students.

In 1868 the demand for trained chemists in this country was very small. At that time even the iron and steel industries did not perceive the advantage of controlling their various processes by careful and accurate analyses.

Andrew Carnegie was the first steel manufacturer who saw the importance of having trained chemists in his works, and in a short address made several years ago he said that one important cause contributing largely to his success was this fact. Such being the case, there was, at the time the institute was opened, little inducement for students to take up the subject of chemistry with the idea of following it as a profession, and though in the first catalogue issued the courses of study announced were mechanical engineering, civil engineering

and chemistry, the only difference in the work of the mechanical engineering department and the chemical department was that the time devoted to shop practise by students in mechanical engineering was spent in the chemical laboratory by those who had taken up the chemical course, and the time in the chemical laboratory was devoted entirely to analytical work. Such important subjects as organic chemistry, industrial chemistry and physical chemistry received no attention. All the work of the department was done in one room, which was also used for the little laboratory work that was given to the students in other courses.

As an illustration of the slight demand there was for chemists, the catalogues show that in the first six classes that graduated from the institute there is only one graduate who followed in after years the profession of chemistry.

Starting in 1868 with only one instructor in chemistry, and only one room for the laboratory, the department of chemistry, at the present time, 1906, has six instructors and separate laboratories for general chemistry, analytical chemistry, organic chemistry, industrial chemistry, sanitary chemistry and biological chemistry.

The work of the department has increased in a like manner. Where in 1868 instruction was only given in two main subjects, general and analytical chemistry, instruction is now given in fourteen different branches of chemistry. The cause of this increase, besides the increase demanded by the growth of the institute, is due to the difference in the positions now opened to chemists. In the early years of the institute the position offered to the graduate from the chemical department were practically that of the analyst, one who could make an examination of iron and steel. No knowledge of organic chemistry, or physical chemistry, or industrial chemistry, or sanitary chemistry was expected and electrochemistry was an unknown science. If the graduate from the chemical department could make a chemical analysis, that was all that was demanded or desired. To-day, this is very different, for the positions offered to chemists require at least a fundamental knowledge of the various branches of chemistry, and one who is only fitted for an analyst has very little prospect of ever rising to any prominent or satisfactory position. This is due to the fact that there is hardly a large manufacturing company that does not now require a chemist, not merely to make analyses, but for the study and the improvement of processes.

Sanitary science in all its branches, agricultural chemistry and electrochemistry all demand chemists, and in every one of these branches will be found men trained in chemistry at the institute.

America is also beginning to follow the German plan, namely, to have connected with the most important manufacturing processes a research laboratory where chemists are employed in strictly research work, not with the work that is being done day by day in the factory, but on problems that, starting from theoretical ideas, may be tested to prove their commercial worth.

An interesting statement in a recent address by James M. Dodge, then president of the American Society of Mechanical Engineers, which is confirmed by the experience of our own graduates, reveals the fact that the average annual salary of the technical trained man is over \$2,150, and for the nontechnical, but trade trained man, \$790, so that the gain in average annual income due to a technical training is over \$1,360. This amount capitalized at 4 per cent. gives to a man receiving a technical training a potential increase in value of \$34,000. There are over one thousand liv-

ing graduates of the institute, to make no mention of an equal number who have spent more or less time at the institute, but who have not taken a degree, so that at the lowest computation the work of the institute since its incorporation, if measured in dollars and cents alone, would represent a capitalization of over $34,000,000. This represents merely a capitalization of the increased earning power of our graduates and takes no account of the enterprises which they have developed and which they direct, which would easily make the pecuniary measure of the contribution of our graduates to the world's assets a sum not less than $50,000,000.

Let us see if on this basis the state, the county and the city have not been great gainers by reason of the work of this institution.

The commonwealth from the earliest time has aided the cause of education, but has now withdrawn pecuniary aid from all the higher institutions of learning excepting from the three schools within her borders which are occupied with the problem of technical education, namely, the Massachusetts Institute of Technology, the Agricultural College at Amherst and the Polytechnic Institute at Worcester. To this school the commonwealth has given the sum of $200,000 in cash and makes an annual payment of $10,000 in consideration of which the institute educates 40 students who pay no tuition, at an expense to the institute of over $12,000 annually. But this by no means measures the benefit conferred by the school upon the state.

There are now engaged in active life in this commonwealth 397 of our graduates which represents directly and indirectly a wealth-creating power represented by a capitalization of approximately $20,000,000, against which may be set the $225,000 which has been received from the commonwealth during the period, making the balance against the commonwealth a considerable one. There are now engaged in active life in this county 214 of our graduates who represent directly and indirectly a wealth-creating power represented by a capitalization of $10,000,000. Certainly Mr. Boynton's gift of $100,000 for the benefit of the youth of Worcester County has borne fruit at least an hundred fold. There are now engaged in active life in the city of Worcester 173 of our graduates, representing upon the basis we have adopted a capitalization of $8,750,000.

Including the recent gift and bequest of Mr. Salisbury, the value of all our property, real and personal, is in round numbers $1,300,000, of which $1,000,000 has been contributed by citizens of Worcester. What a rich return upon the investment!

In addition to this, the institute, at an annual expense of about $300 per student, is educating at the present time over 100 Worcester boys a year, for which is paid the regular tuition of $160 per year, which equals but little more than one half of the cost, so that the institute is contributing to the youth of the city educational advantages which cost it $15,000 annually. Is there not abundant reason for the belief that when the need arises the citizens of Worcester will contribute generously to the funds of the institute?

Worcester is peculiarly dependent upon the brains of her people for her prosperity, much of which is due to our technically trained men who are directing the industrial affairs of the city, and upon whom the city must largely depend for future prosperity. Such in brief is the debt of the state, the county and the city to the school.

Since its organization something over two thousand students have been members of the institute. Eliminating from consideration all who did not graduate, the cost

to the institute of educating the 1,095 students who graduated has been $1,037,834, and there has been received from these students in the form of tuition fees the sum of $273,483. In other words the cost of education of the graduates has exceeded by $764,351 the amount received from them. In this computation no account is taken of the investment in plant and equipment which would increase the amount by about $400,000. In good time, I doubt not, the alumni who are able to do so will be glad to treat this as an obligation which they will take pleasure in discharging, though the facts are not mentioned here for the purpose of unduly emphasizing what might perhaps be regarded as a disquieting suggestion.

The application of science to the useful arts has had a controlling influence upon the political as well as the economic history of the world.

In 1814 Mr. Calhoun favored double duties as a protective measure. Mr. Webster, then senator from Massachusetts, opposed this policy. How strange his words sound to-day:

> I am not in haste to see Sheffields and Birminghams in America. I am not anxious to accelerate the approach of the period when the great mass of American labor shall not find its employment in the field.

In 1828, when a large investment had been made in manufacturing industries in Massachusetts, Mr. Webster had changed his position and favored the tariff. But the tariff was resisted by South Carolina, and the legislature of that state put forth the famous 'exposition and protest' containing Mr. Calhoun's doctrine of nullification. Thus was the position of these great men entirely reversed upon the question of the tariff. The explanation is very simple.

In 1791 our cotton was all imported, and the south wanted a duty to encourage its domestic production. The invention of the cotton gin by Eli Whitney, in 1793, a Worcester County boy, already referred to, which made it easy to separate the green cotton seed from the staple, revolutionized the cotton industry and made the south independent of the tariff. The invention of the cotton gin compelled the enunciation of the doctrine of nullification. The doctrine of nullification compelled the civil war.

Knowledge of engineering makes possible such great works as the building of the Suez Canal, which has revolutionized the trade relations between Europe and the east; the building of the great dam at Assouan to store the surplus water of the Nile; the construction now fairly beginning of the Panama Canal.

Another striking illustration is found in the policy adopted by the national government in the act of Congress of June 17, 1902, appropriating the receipts from the sale and disposal of public lands in certain states and territories to the construction of irrigation works for the reclamation of arid lands which cover about two fifths of the area of the United States. This fund now amounts to about $30,000,000, and projects under consideration in fourteen states contemplate the irrigation of 1,441,000 acres of land at an average cost of $25 per acre. A single example may be found in the work now under way in Wyoming in the portion of the Big Horn basin on the north side of the Shoshone River seventy-five miles east of Yellowstone Park.

This involves the construction of a dam seventy-five feet wide at the bottom of the channel and 200 feet wide at an elevation of 240 feet, the proposed height of the dam above the river bed, and the building of a spill-way connecting with a tunnel through the solid granite of the mountain. The canyon is so narrow that it is regarded as feasible to enclose the entire area covered

by the dam so that the enclosure may be heated and the work carried on during the winter. It is anticipated that 175,000 acres of land will thus be reclaimed, and that a population of 50,000 people will be added to a community now thinly settled. This great work, primarily of the civil engineer, is contributed to by almost all departments of applied science. Suitable foundations for the dam must first be found. The mechanical engineer explores with his drills; the geologist and the chemist determine the character of soil and rock; the civil engineer plans and constructs; the electrical engineer takes power developed from storage reservoirs and transmits it electrically to pumping areas and installs a telephone service so that the system may be safely and efficiently administered.

The once naked savage, who, perhaps, almost dying of hunger and thirst, feebly directed his tottering steps over these lonely and unfruitful regions, now at daily wages, which ensure him every comfort, participates as a citizen of the United States in this beneficent undertaking. In place of desolation will be found a large and intelligent population busily engaged in agricultural pursuits and all the attendant industries, while the church, the school, the college—companions of the highest type of civilization—create and minister to the noblest aspirations of a prosperous community. Thus does applied science contribute to the advancement of mankind.

One most potent influence in our industrial development has been our system of patent law. The patent office was created by the act of 1836. Up to January, 1861, 31,000 patents had been issued. Up to January, 1906, something more than 800,000. Under the stimulus of these laws the inventive faculty of our people has exceeded that of any other country. In the administration of these laws within the patent office and in the practise under them without, there are now engaged more than thirty of our own graduates who are peculiarly fitted because of their training to succeed in this important field.

The industrial development of the world has been stimulated by the great expositions which have been held from time to time in different countries. That of England in 1851; at New York in 1853; at Paris in 1855; again in England in 1862; in Paris in 1867, greatest of all up to that time; at Vienna in 1873; at Philadelphia in 1876; at Paris in 1878; at Chicago in 1893; and at St. Louis in 1904.

I have recently seen the statement that modern technical education is the direct result of the London exhibition of 1851, where for the first time was given an opportunity to see side by side the industrial products of all nations. However this may be, it is certainly true that the event was one of great importance to the industrial world.

In February, 1850, the first of the great public meetings on the subject was held in England. France, Prussia, America and Belgium were represented. Lord Morpeth, who presided at the meeting, in closing his speech, said:

> I can not better sum all that may be said than in words written nearly a century and a half ago. Listen, ladies and gentlemen, and see if Pope was not almost as good a prophet as he was a poet:
>
> The time shall come, when, free as seas or wind,
> Unbounded Thames shall flow for all mankind,
> Whole nations enter with each swelling tide
> And seas but join the regions they divide;
> Earth's distant ends our glories shall behold
> And the new world launch forth to seek the old.

The Prince Consort, to whom the chief credit is due for the inception and management of the great enterprise, made a speech at the Mansion House in March, 1850, in which he said of the purpose of the exhibition that it was to

give the world a true test, a living picture, of the point of individual development at which the whole of mankind has arrived, and a new starting point from which all nations will be able to direct their future exertions.

How well it served its purpose is demonstrated by the fact that at the exposition in Paris in 1867 England found that while in 1851 her supremacy had been undisputed, in 1867 out of 90 departments she had superiority in only 10. An investigation led to the conclusion that the cause of this was the better scientific instruction given to artisans on the Continent. France, Prussia, Austria, Belgium and Switzerland possessed good systems of industrial education for the masters and managers of factories and workshops, while England possessed none.

An Englishman, a judge in the class of woolen textile fabrics, said, speaking of the continental workmen:

Brains sit at the loom and intelligence stands at the spinning wheel.

At this exposition the progress of France and Germany was especially commented upon.

Sir Lyon Playfair, speaking some years ago of the influence of technical education upon the industrial prosperity of Switzerland, said:

The Coventry ribbon trade, which has deserted England, has settled in the valleys of Switzerland. The polytechnic institute has aided in this result, because it turns out seventy or more persons annually, trained in the science and art requisite to conduct such a manufacture successfully.

This single branch of manufacture so transferred from England to Switzerland employs in the latter thirty thousand weavers and other collateral workers, such as dyers and superintendents. The value of the annual export of this manufacture from Switzerland is eight million dollars, while the trade has languished at Coventry in England until the annual export is little more than three hundred thousand dollars.

"The difference," says Lord Lyon, between the Swiss trade and the Coventry trade, "is very simple; it is involved in the answer given by Opie, the painter, to a youth who asked him how he mixed his colors—'I mix them with my brains, sir.'"

It is a striking fact that England, which has produced Arkwright, Watt, Stephenson and Bessemer and others equally distinguished, should have been unable to keep pace with other nations in the application and development of the principles which these men first disclosed. It may be accounted for in some degree at least by another surprising fact, that in industrial education England is excelled by all the leading nations of the world.

There is undoubtedly a demand in this country at the present time for the education of those in our industries who need the skill of the mechanic and an order of intelligence superior to that of the ordinary workman. This has long been recognized and has been met in some slight degree both within and without this commonwealth. This need is more apparent than ever at the present time when the specialization of industries has reached a point where the old-fashioned all-around mechanic is becoming more and more difficult to find.

While there is no great dearth of engineers, there is a short supply of skilled workmen of intelligence. This is a department of industrial education that can not be safely neglected. Germany has appreciated this fact, and leads all the countries of the world in this as in all other departments of technical education, and owes to this, very largely, her present industrial position.

President Alderson, of the Colorado School of Mines, in a recent article, speaks as follows of present conditions:

There are six building and mechanical trade schools in New York and Brooklyn, three in Boston, two in San Francisco, and two in Philadelphia. New York has two brewing academies; Chicago and Milwaukee one each. Philadelphia, Lowell, New Bedford and Atlanta have textile

schools. Chicago, St. Louis, Omaha, Peoria, Waltham, Winona and LaPorte have watch making and engravers' schools. The universities of Wisconsin and Minnesota, and the Iowa College of Agriculture have schools of dairying. For dressmaking, millinery and the domestic arts and science, schools exist in Boston, New York, Brooklyn, St. Louis and Philadelphia. Eight cities contain schools to teach barbering. St. Louis has a school for railway telegraphers; Effingham, Illinois, a college of photography, and New York an academy for shipbuilders.

Still another extension of technical education is to be noticed in our large cities, where technical schools have opened their doors in the evening and have invited students, employed during the day, to enter and learn what they can. These night schools are exceedingly common in England, so common that they have undermined the influence of the regular day schools and have implanted the erroneous idea in the mind of the average young Englishman that he can work all day, go to school at night, and still be successful in each case. Such we know to be fallacious. The true conception of night school work is that it is only a means of securing essential facts, but is not education in its truest sense. The Germans have not made this mistake and emphasize the necessity of giving undivided attention either to educational work or to industrial work, but not to combine the two. Interesting in connection with evening instruction by technical schools is the use of local centers or technical clubs, with home-rule organization, but with the same end in view.

At the end of this list must be added the educational work of the Y. M. C. A., which quietly but effectually reaches thousands of students. All these influences combined reach an industrial army that can be counted in the millions. The movement for more technical education is certainly far-reaching and important.

He also expresses the opinion that at one time or another not less than two million in the United States have taken one or more courses in some correspondence school. The industrial training given at Tuskegee is another indication of the great value placed upon it as an essential part of education and possesses additional interest and importance from the fact that it is regarded as the most efficient manner in which to permanently improve the condition of the negro in the south.

In our own state, the Lowell Textile School opened in October, 1897; that in New Bedford in October, 1899, and that in Fall River in 1900. These, in Massachusetts, are trade schools of a pure type, and serving a most useful purpose, supported in part by the commonwealth in the interests of the textile industries which from the earliest times have been so important to our people.

This need was recognized by the advisory committee invited by the trustees of the Carnegie gift to present a plan for the technical school to be established at Pittsburg. They recommended the establishment of the (1) Carnegie Technical College; (2) Carnegie Technical High School, where is to be taught engineering principles, steam engine practise, pattern making, tool making, etc.; (3) Carnegie day and evening classes for artisans. The two latter recommendations attempt to provide for the need of which I have spoken. This plan seems to be modeled upon that of Norway, proposed in 1868, involving Sunday and evening schools for mechanics, elementary technical schools of a practical character and a polytechnic institute of the highest grade.

The subject of industrial and technical education in this commonwealth has been recently considered in the report of a committee appointed under the authority of the legislature of which our accomplished fellow townsman, Dr. Carroll D. Wright, president of Clark College, is the chairman. His attainments in industrial economics make this report of authoritative value. In it the need in this country is recognized of more skilled workmen, of those possessing not so much manual dexterity as 'industrial intelligence,' by which is meant—and I now quote from the report—

Mental power to see beyond the task which occupies the hands for the moment to the operations which have preceded and to those which will follow it—power to take in the whole process, knowledge of materials, ideas of cost, ideas of organization, business sense, and a conscience which recognizes obligations.

This need the committee believes should be met by industrial education in the public schools and through independent industrial schools; such instruction is, of course, designed for students younger than those with whom we have to deal here, and is of an entirely different grade and character, but, nevertheless, is of very great importance. In this report the Massachusetts Institute and the Worcester Polytechnic are spoken of as institutions which train mechanical and electrical engineers, manufacturing chemists and architects—men in the highest ranks of productive industrial life; institutions which have fully justified all that they have cost and of world-wide fame.

If I may borrow further from this interesting report, I will add that the system of industrial and technical education in the German empire is held up as an example, and a comparison is made which shows that if Massachusetts were to maintain a system of industrial schools of proportionate development with that of the kingdom of Prussia, we should need three hundred such schools with a total enrollment of twenty thousand.

It would be idle to assert that the industrial supremacy of the United States is due primarily to our system of industrial education, because, as a matter of fact, we are inferior in this respect at least to Germany, France and Switzerland. But the time is certainly fast approaching when we must take heed of the industrial competition from other countries which are adopting our machinery and methods, stimulated by what they learn at the great expositions. It is certain that without great effort we can not retain our supremacy undisputed; and for this reason it behooves us to pay particular attention to the industrial education of our people.

Just as in agriculture, after the virgin soil begins to be exhausted by wasteful methods of cultivation, scientific methods must be employed if the quantity and quality of crops are to be maintained; so in other industrial pursuits—as competition forces prices down, the labor must be more intelligent, the scientific knowledge more exact, if satisfactory results are to be secured.

It is a mistake to think, as is often said in this country, that the 'pauper labor' of Europe is a menace to us. It is rather the educated labor of European competitors of which we should stand in fear.

I believe it to be true to-day that in a large number of our industries in which labor-saving machinery is used to any considerable extent, the cost of labor per unit is less than in any country in the world, and for the reason that our labor is so much more efficient.

As men with a technical education are the ones who will manage our railways and great manufacturing plants, they naturally have a deep interest in, and should have an intelligent knowledge of, the changing conditions under which business is being done, information which our own students acquire in the department of political science.

The factory system was a product of the close of the eighteenth century—the trust, so-called, of the close of the nineteenth; and great abuses have attended each change, which are quite independent and separable from the system which they accompanied.

The great cruelties attendant upon the labor of women and children were a blot upon the former. These have happily largely disappeared before the corrective

of intelligent legislation—and the same remedy will no doubt be efficiently applied in due time to the evils attendant upon the latter, to which the attention of the whole country is now directed.

To consolidation as such, I think there can be no rational objection, and I will hazard the opinion that competent young men who are obliged to stand absolutely on their own merits have a better chance to succeed to-day than ever before in the history of the country. The time at my command—already, I fear, exhausted, as well as your patience—does not admit here of any extended discussion of this interesting question.

The 'good old times' were not as good as these, and I believe that these are not as good as those that are to come. Macaulay, who so richly embellishes every subject he touches, uses the following illustration:

> In truth, we are under a deception similar to that which misleads the traveler in the Arabian desert. Beneath the caravan all is dry and bare; but far in advance and far in the rear is the semblance of refreshing waters. The pilgrims hasten forward, and find nothing but sand where, an hour before, they had seen a lake; they turn their eyes, and see a lake where, an hour before, they were toiling through sand. A similar illusion seems to haunt nations through every stage of the long progress from poverty and barbarism to the highest degrees of opulence and civilization. But, if we resolutely chase the mirage backward, we shall find it recede before us into the regions of fabulous antiquity.

At no time has the question of the rights of the people, as against those of the so-called vested interests, been as prominent, I may say as all-absorbing, as at this moment. Forty years ago the government was encouraging the building of railroads by enormous grants of land. The chief desire of the nation and the states was to get the means of transportation at any cost. The recent session of Congress has been largely devoted to devising means for regulating railroad rates—already at a lower point than any one twenty years ago would have dared to predict. I have no quarrel with this wholesome legislation. I merely use the incident as an illustration. This is the day of the reasonable control of business and of the elimination of abuses which have inevitably sprung up alongside and been dwarfed by an industrial development more rapid and more stupendous than any that the world has ever seen. In this important work, educated men and, above all, technically educated men, should take the lead, if it is to be well done, and done it will be. The conscience of the country has been quickened as never before, largely, I believe, through the initiative of the president of the United States, who only needs to see a wrong to exert all the prerogatives of his great office to remedy it.

Happy that land where the people govern; where education is not for the cloistered few but within the reach of every child; where the limits to ambition are only those prescribed by the ability and disposition of the individual, and which advances from generation to generation to better and better things.

CHARLES G. WASHBURN.

SCIENTIFIC BOOKS.

The Biology of the Frog. By SAMUEL J. HOLMES, Ph.D., Assistant Professor of Zoology in the University of Wisconsin. New York, The Macmillan Co. 1906. $1.60 net.

A most useful addition to our text-books on the frog. It presents not only the anatomy and embryology but also the physiology and natural history of the frog; so that for the first time a single book covering the whole ground of the biology of the frog is accessible to teacher and student.

The text of 358 pages is divided into nineteen chapters. The first places the particular kind of frog (the leopard frog, *Rana pipiens*), which is the chief subject of the volume, in proper relation to other kinds of frogs and to the salamanders by a brief consideration of

the classification of the amphibia with special reference to the common American forms and their habits. The second is one of the most interesting of all and considers in some three dozen pages the life and habits of this common frog; recounting its methods of locomotion and of feeding; describing its voice, enemies, parasites, as well as its breeding habits and its responses to changes in temperature, etc.

The succeeding two chapters briefly describe the exterior of the frog and the main features of its internal structure, reserving for later chapters detailed descriptions of anatomy and physiology. The fifth chapter devotes some 38 pages to the embryology of the frog from the time the egg is laid through the metamorphosis into the adult shape, and includes a brief historical introduction. Chapter six presents a brief outline of vertebrate histology as illustrated in the frog, while chapter seven takes up the digestive organs rather fully, with special emphasis upon glandular activity. The eighth chapter deals with organs of voice and of respiration from a physiological standpoint and leads to the ninth chapter, which is devoted entirely to the skin, an undue amount of space being devoted to its color changes.

The excretory organs and the reproductive organs each receive a chapter descriptive of their anatomy and functions.

The devotion of an entire chapter to the subject of internal secretions is timely and the restriction of the treatment of the skeleton to a single chapter of fifteen pages shows commendable restraint, considering the large amount of detail that might so readily have been retained here.

From the point of view of the student the ten pages devoted to the muscles might well have been made fewer.

The fifteenth chapter describes the microscopic structure of the blood, the anatomy and action of the heart, the distribution of the veins and arteries and the circulation as seen in the web of the foot, with also a brief consideration of the lymph system.

The sixteenth chapter gives a good description of the anatomy of the nervous system and considers reflex actions and the conflicting evidence as to the functions of the various parts of the brain: so that 35 pages are needed.

The structure and uses of the sense organs are adequately treated of in some 20 pages.

The last two chapters deal with the instincts, tropisms and intelligence of the frog as known from the works of Yerkes, Parker and others. Probably the presentation given will give the student a just conception of the rather confused and tentative nature of the results thus far gained by the experimental study of the psychology of the frog.

The author has prepared the book as the outcome of six years of lectures given to students who had studied some general biology. As a compilation it gives the gist of the anatomy and histology of Gaupp's 'Ecker,' and enough of the embryology of Marshall and deserves great praise for bringing together in attractive form much of the scattered knowledge of the natural history and physiology of the frog. To be commended is the list of authors at the end of each chapter and the impression conveyed that the conclusions reached in the physiology and psychology of the frog are complex balancings of diverse facts and opinions while suspended judgment is often imperative.

The 94 illustrations are, with few exceptions, the familiar figures of Ecker, Howe and Marshall and while one need not expect many illustrations for a physiological presentation of the subject yet one could wish that the excellent photographs used as a frontispiece might have been followed by others illustrating the natural history of the frog.

While the book is easily read and the author's meaning clear, some hypothetical student punctilious as to English but ignorant of natural history, might be misled in reading of the feeding habits of the toad, page 14: 'angleworms are seized by the jaws and stuffed into the mouth by the fore legs.'

Every teacher of vertebrate zoology will need a copy of the book and many college students will find it a valuable text-book. But while the central idea of adding physiology and natural history to anatomy and embryology is a good one, it almost necessarily leads to putting too much knowledge before the student. In a second edition, for which we

hope there soon may be demand, the author might perhaps better satisfy a larger number of students by a thoroughly digested epitome of the present book, while the teacher should welcome another volume that would still further elaborate all but the anatomical part of the present book. For the teacher there might be added a consideration of the geographical distribution of frogs, with maps; a full discussion of the remarkable breeding and brooding habits of some exotic frogs; more ample reference to the field of regeneration in frogs; an account of the genesis of the egg and the sperm; and original illustrations. He would then have a fit complementary volume to Gaupp's 'Ecker.' E. A. A.

Easy Mathematics, chiefly arithmetic; being a collection of hints to teachers, parents, self-taught students and adults, and containing most things in elementary mathematics useful to be known. By Sir Oliver Lodge, F.R.S. Macmillan and Co. 1905. Pp. xv + 436.

When a man like Sir Oliver Lodge writes on arithmetic we naturally expect an unusually high motive. In the present case this motive is set forth in such forceful terms as follow:

> The mathematical ignorance of the average educated person has always been complete and shameless, and recently I have become so impressed with the unedifying character of much of the arithmetical teaching to which ordinary children are liable to be exposed that I have ceased to wonder at the widespread ignorance, and have felt impelled to try and take some steps towards supplying a remedy. The object in writing the book has been solely the earnest hope that the teaching of this subject may improve and may become lively and interesting. Dulness and bad teaching are synonymous terms. A few children are born mentally deficient, but a number are gradually made so by the efforts made to train their growing faculties.

To read an arithmetic written in a breezy style yet thoroughly sane from cover to cover is a surprisingly interesting experience for most people who try it. While those who are familiar with elementary mathematics may not learn any new facts by reading this book, yet there will probably be few who will not have a more cordial attitude towards the subject. It works a change of feeling and clearness of vision rather than a deeper insight into the more abstruse parts.

The charm of many illustrations lies in their extreme simplicity. For instance:

> It is very often a mistake for teachers to suppose that some things are easy and other things are hard; it all depends on the way they are presented and on the stage at which they are introduced. To ascend to the first floor of a house is difficult if no staircase is provided, but with a proper staircase it only needs a little patience to ascend to the roof. The same sort of steps are met with all the way, only there are more of them. To people who live habitually on the third floor it is indeed sometimes easier to go on the roof than to descend into the basement. Educators should see that they do not forcibly drive children in shoals up an unfinished or ill-made stairway, which only the athletic ones can climb.[1]

The first part of the volume is partly historical. In some of this the imagination is explicitly allowed to wander beyond the established facts. In addition to most of the questions which are met in arithmetic and elementary algebra, there are chapters on *Easy Mode of Treating Problems that require a Little Thought, dealing with Very Large or Very Small Numbers; Pumps and Leaks, Differentiation, etc.* The work is divided into forty-seven brief chapters and throughout impresses one with the fact that the greatness of a man is perhaps most strikingly exhibited by his treatment of common subjects. The author with a narrow outlook would not make such a wise choice of subject matter and would not be apt to refresh the reader with such broad views as 'Real living arithmetic is the same in any country; and most important of all is that which must necessarily be the same on any planet,' and 'An equation is the most serious and important thing in mathematics.'

While the book naturally appeals most strongly to the teacher, yet it seems to be eminently suitable for those who desire to get a clear view of the subject matter which has been employed in their early training. The sub-title has a quaint eighteenth century flavor, but the book itself is thoroughly modern

[1] Page 13.

and may be regarded as one of the best expressions of the spirit of the recent reform movement in mathematical instruction.

G. A. Miller.

Stanford University, California.

SOCIETIES AND ACADEMIES.

THE ST. LOUIS CHEMICAL SOCIETY.

At the regular meeting of the society on Monday, June 11, Mr. W. R. Lamar presented a paper entitled 'Recent Investigations on the Constitution of Certain Alkaloids.' After a few preliminary remarks on the difficulties encountered in determining the molecular constitution of these substances and on the methods employed for the purpose, the paper was devoted to four substances: namely, conine, nicotine, atropine and cocaine. The society was treated to an exceedingly comprehensive and condensed account of the investigations into the constitution of each of these bodies, indicating the failures as well as the partial and complete successes. This was followed in the case of each substance by a similar account of the efforts at producing the same substances synthetically.

C. J. Borgmeyer,
Corresponding Secretary.

DISCUSSION AND CORRESPONDENCE.

THE HAILSTORM OF JUNE 23.

To the Editor of Science: During the storm which swept the Atlantic coast on Saturday, June 23, the hailstones which fell at Perth Amboy, N. J., and vicinity were of such large size that the following observations from a house on the shore of Raritan Bay may be worth recording. The hailstorm was preceded by the piling up of great masses of cumulus clouds, while out in the Lower Bay a tornado caused a waterspout; there was also considerable lightning and a brief heavy shower of rain, so that the usual conditions for a severe hailstorm were satisfied. About four o'clock big hailstones began to bombard the house, at first few in number and in a very slanting direction, then in a roaring downpour that made the bay spout up into thousands of white geysers. This lasted, perhaps, five minutes.

We immediately gathered some of the hailstones which thickly dotted the lawn. They ranged from the size of a cherry to that of a duck's egg, the larger ones being very abundant. The smaller ones were more or less spherical, consisting internally of broad concentric zones of softer, more snow-like, and of harder, darker ice, the broken surfaces reminding one of polished sections of concretionary nodules of agate. The larger ones were oblate spheroids, oval in contour, with crater-like depressions in the center of each flattened side. The largest ones filled the palm of the hand, and upon being measured with great care proved to be not less than three and one eighth inches along the long diameter and eight inches in circumference. The surface was irregularly tuberculated, and the center, core or axis of the spheroid was always distinct, appearing in broken hailstones as a small white spot. None were observed in which the nuclei were formed of small pebbles. The hailstones seemed harder to crack in the teeth than ordinary ice.

The impact of their fall caused circular depressions in the hard-packed tennis court, and later on the soft sand of the beach the still unmelted kernel of each hailstone was found in a depression containing a close coil or many concentric circles of sand.

Mr. George H. Pepper, of the American Museum of Natural History, who also observed the same storm in Tottenville, at the southern end of Staten Island, appends the following notes:

The first evidence of the storm in Tottenville was a heavy rain accompanied by a shower of small hailstones about the size of a pea; these stones were similar to snow ice. The rain continued and after an interval of perhaps five minutes a second shower of hailstones was noticed; these ranged from the size of hickory nuts to walnuts. The fall of these stones was followed by the larger ones, the intervals being, perhaps, two or three minutes. The shower carrying the large hailstones lasted not more than three minutes, but during that time twenty-five glasses were broken in the house in which I happened to be. Over fifty glasses in memorial windows

of one of the churches were broken, and almost every house having windows on the western side suffered from the stones. One of the largest stones was measured, the result showing a circumference of nine inches; it was irregular in form, one and a half inch thick and the edge was deeply indented in places. This was not an exceptional stone, as a great many of this size were found.

W. K. GREGORY.

AMERICAN MUSEUM OF NATURAL HISTORY.

SAUROPODAN GASTROLITHS.

TO THE EDITOR OF SCIENCE: It may be of interest, in connection with Mr. G. R. Wieland's recent description of the gastroliths found with the sauropod remains in Montana, to call attention to an apparently unrecorded similar discovery at Morrison, Colo. In 1877, Professor O. C. Marsh's party, in charge of Professor Arthur Lakes, obtained among the bones of the type specimen of *Atlantosaurus immanis* Marsh, a number of rounded and highly polished siliceous pebbles whose surface peculiarities resembled those of the gastroliths described by Mr. Wieland. No material of similar size, form, surface markings or composition occurs elsewhere in the Atlantosaurus clays of this vicinity. Professors B. F. Mudge and S. W. Williston were with us when some of these pebbles were found and considered them as identical in origin with the stomach stones that they had recently found with plesiosaurian remains on the plains of Kansas. With the exception of one specimen, now in the collection of fossils in the Denver High School, these specimens were probably sent to the Peabody Museum of the Yale University and might be found in the collections sent to Professor Marsh by Professors Lakes and Mudge from the neighborhood of Morrison during the years 1877 and 1878. The field notes of Messrs. Lakes, Mudge and Williston, if obtainable, might afford additional data and possibly confirm a suspicion of the writer that some gastroliths were also found in connection with the type specimen of the species formerly known as *Apatosaurus ajax* Marsh.

GEO. L. CANNON.

DENVER, COLO.

THE SMITHSONIAN INSTITUTION AN INSTITUTE OF RESEARCH.

TO THE EDITOR OF SCIENCE: I desire to emphasize the suggestion made by David Fairchild in SCIENCE for June 8, in which he advocates changing the Smithsonian Institution from a museum to an institute of research. It seems to me that this idea ought to appeal strongly to men of science generally throughout the country. It can not be denied that the greatest impetus to research in pure science in the past has been the working together of men earnestly engaged in special lines of research, and the value of such researches has been greater whenever the several investigators have been brought together in one institution or in one laboratory. Experience has shown that under such conditions only as are found, for example, in the Biological Station at Naples, or in the laboratories of the greater German universities, does the most stimulating atmosphere of research exist.

The elaborate and well-endowed scientific projects now in operation, although extremely valuable, can not do for the progress of knowledge what such institutions as the above mentioned are doing. We have in this country large and well-endowed museums that are amply able to care for the work that falls within their respective provinces, but there is no institution that can be looked upon as a common center of research to which the investigator may go to pursue his studies with the necessary equipment and in an atmosphere whose vigor comes from the helpful suggestions and from the keen but friendly criticism of his many colleagues.

Let the Smithsonian Institution, therefore, be the nucleus of such a great national or international institute of research.

DAVID M. MOTTIER.

INDIANA UNIVERSITY.

SPECIAL ARTICLES.

EVIDENCES OF GLACIATION IN SOUTHERN ARIZONA AND NORTHERN SONORA.

IN the spring of 1905, during a professional trip to Sonora the writer was interested in observing along the Sonora Railway, south of

Nogales, frequent exposures of material resembling in every way, except in its component rocks, that of the terminal moraine of New York and New Jersey. These exposures were between Nogales and Imuris, occurring frequently in a distance of some fifty miles, and exhibited sections of till and boulder clay with large angular rock fragments and the occasional partial stratification characteristic of various portions of the terminal moraine in the northeast.

Having then no opportunity to verify these observations, they were briefly noted, to be amplified on some future occasion.

During the months of April and May of the present year, a further opportunity was afforded to traverse the same country and secure additional data bearing on the phenomena mentioned.

These last observations have convinced me that there is, in the vicinity of Nogales, both in Arizona and in Sonora, and for a number of miles north and south of the national boundary, an area of some width in which land ice transportation has been operative and has resulted in the formation of morainal deposits of various types.

A complete absence of detailed maps in northern Sonora makes it difficult, without extended study in the field, to form any generalizations concerning the centers of accumulation from which the glacier or glaciers may have flowed.

In Arizona, the publication, during 1905, of the Nogales, Patagonia and Tucson quadrangles affords an opportunity to locate the more important phenomena observed and determine the possible sources of ice action.

Some ten miles north of Nogales rises from the general level of the surrounding desert country a high range known as the Santa Rita Mountains. At the desert level, which is about 2,700 feet, this range has a base approximately thirty miles long and from eight to fifteen miles wide. Its highest peak has an altitude of 9,400 feet and a considerable area of the range (perhaps twenty square miles) is above the six-thousand-foot level. Within a mile or two of the southeastern base of the range passes the Sonora Railway, which, here as in Sonora, by its numerous cuts and borrow pits, gives an opportunity to study the composition of a formation which has all the characteristics of a moraine deposit, but which, in the absence of sections, a casual observer might pass by as a terrane of volcanic material rotted in place.

In connection with the structure exposed by the sections, one recognizes at many points the rolling topography and pitted surface of a moraine. At one or two points are observed depressions, similar to those which in the north have been formed by stagnant ice, surrounded by kame terraces and their concordant phenomena. One of these is just south of Huachuca Station.

About three miles south of Nogales is a very extensive borrow pit, formed in the construction of the railroad, in which has been left a number of large rock fragments which are clearly of transported material. Among these, the writer noted several blocks of dark blue limestone which did not belong to the crystalline terrane beneath and which had evidently been transported some distance.

A marked difference between the transported material here and that in the north lies in the comparative absence of large boulders, for none were seen to exceed about two feet in diameter. This is probably due to the character of the volcanic rocks and their manner of decay. A cliff of andesite or rhyolite does not in Arizona or Sonora seem to yield talus fragments of as large size as a cliff of granite or gneiss in New York.

The total extent of these glacial formations could not be determined without an extended reconnoissance which the writer had not time to make, but they are apparently limited to the vicinity of the higher mountain ranges. About twenty miles west of the Santa Rita Mountains, between Sopori and Arivaca, on the west of the Atascosa Range, is a long stretch of low hills and rolling country, trending southwesterly, which has a morainal appearance; but in the absence of sections no decisive conclusion was reached.

In northern Sonora, near the valley occu-

pied by the railroad and between Nogales and Imuris, one sees near the mountain bases low benches which have been eroded into overlapping oblique ridges of which the material seems to be all of morainal character. These overlapping ridges form prominent features in the landscape and are locally called by the Mexicans *cordones*, or 'chains.' They have not been observed by the writer south of Magdalena.

In traveling eastward from Benson toward El Paso, at a few points, mountain masses were observed, rising from the desert plains, around the bases of which were slightly elevated benches corresponding in some measure to the bench of morainal material along the eastern base of the Santa Rita Mountains. Occasionally, also, the railroad cut through low rolling ridges of material, morainal in structure and clearly not formed by sheet flood erosion.

On the Rock Island Railway, about a mile southwest of Santa Rosa, N. M., near the southeastern bank of the Pecos River, is a train of rolling hills which show morainal structure in the railroad cuts.

These observations lead to the conclusion that the quaternary history of some portion of this region is more complex than has been supposed. Clearly before the present period of arid climate and periodic sheet flood erosion was a time of low temperature and accumulated precipitation in the form of land ice which resulted in the formation of extensive deposits of rock debris around the bases of at least the higher mountain ranges. Climatic conditions limited the extent of these moraines so that the present desert basin areas, in many cases, remained unglaciated.

A further point of interest is the hypothesis, suggested by the facts observed, that some of the quaternary conglomerates which are abundant in northern Sonora and are so puzzling in respect to their origin may in part be the result of glaciation. The writer has, so far, been unable to formulate any other theory of origin which will account for the presence, in some of these beds, of boulders as large as two feet in diameter, in a matrix of angular fragments, of many different kinds, mingled with fine material. In a bed of true volcanic breccia one does not ordinarily find several different kinds of eruptive rock varying greatly in composition.

FREDERICK J. H. MERRILL.

NEW YORK CITY.

ZYGOSPORES AND SEXUAL STRAINS IN THE COMMON BREAD MOULD, RHIZOPUS NIGRICANS.[1]

FROM the preliminary communication of J. I. Hamaker in the May 4 number of SCIENCE, entitled 'A Culture Medium for the Zygospores of *Mucor stolonifer*' (*Rhizopus nigricans*), one would be led to suppose that the method of obtaining the zygospores of this species by admixture of strains from different sources was unnecessarily troublesome and uncertain. After having obtained the zygospores frequently for three months, he is brought to the conclusion, which is printed in italics, that 'with proper conditions of moisture and temperature, success is apparently dependent only on the nature of the substratum.' As a favorable substratum, a corn muffin bread is recommended and a detailed formula of the ingredients is given.

In a preliminary summary of a study of the sexual conditions in the Mucorineæ,[2] the present writer has used this same common bread mould *Rhizopus nigricans*, as a type of the heterothallic (*i. e.*, diœcious) group in which each species is to be considered an aggregate of two distinct sexual strains the interaction of which is requisite to zygospore formation. In contrast to homothallic (*i. e.*, hermaphroditic) species in which the mycelia are sexually all equivalent and which may produce zygospores from the sowing of a single sporangiospore, it is necessary in the heterothallic species, in order to obtain the zygospores in pure cultures, to sow spores together from both the sexually opposite strains which have been provisionally designated by the terms

[1] This paper was written while working under a grant as research assistant to the Carnegie Institution.

[2] 'Zygospore Formation a Sexual Process,' SCIENCE, N. S., 19: 864–866. 1904.

(+) and (—). The rarity of the zygospores of heterothallic species therefore may be explained by assuming that when zygospores fail to form under conditions which of themselves are not unfavorable to zygospore formation, only one of the two sexual strains is present.

Ever since de Bary[3] discovered the zygospores of *Rhizopus* in 1865—now forty years ago—various and conflicting theories, based many of them upon the character of the substratum upon which the zygospores were accidentally found, have been brought forward to account for the rarity of their occurrence. The writer has attempted to show the insufficiency of the assumption that external conditions are of more than secondary importance, and has given at the same time a rather full account of cultural experiments with the strains of *Rhizopus*.[4] It is not the purpose of the present article to repeat the details there given. It seems not inappropriate on this occasion, however, to say a few words regarding the occurrence in nature of the strains of this species based upon recent investigations as well as upon those already published. For the sake of comparison, a list of those species the thallic condition of which has been determined, will be given arranged according to the type of their sexual reproduction, and something will be said concerning the cultivation of *Rhizopus* for class purposes.

In Table I. are listed the zygosporic cultures from which the sexual strains have been isolated by the writer. In making the separations, a large number of cultures were necessary as indicated in the table. Tests with both the standard (+) and (—) strains were not made for all the cultures listed, but no strains were found which alone in pure cultures could be brought to zygospore formation.

In the preparation of Table II., the individual strains obtained through the kindness of the writer's correspondents were tested in separate cultures against standard (+) and (—) strains. Each strain therefore listed as (+) or (—) produced zygospores in contrast with the test strain of opposite sign and failed to produce them in cultures with the test strain of the same sign. Those strains which would form zygospores with neither the (+) nor the (—) test strain on the substratum used were provisionally listed as neutral. Judging from the possibility of inducing temporary neutrality in the strains of *Mucor Mucedo* by cultivation under unfavorable temperatures, one might suppose the neutrality in these strains of *Rhizopus* to be likewise but a temporary condition. With their exception, all of the 43 individual strains tested are either (+) or (—). To the 11(+) and 19(—) strains in Table II., should be added the 8(+) and 8(—) strains isolated from the zygosporic cultures of Table I. We shall then have from the strains tested 19(+), 27(—) and 13 apparently neutral. Out of this total of 58 individual strains, none have been found which will yield zygospores when grown alone in pure cultures. As may be seen by a glance at the tables, strains have been collected from various parts of the world, and the conclusion seems irresistible that the common bread mould, *Rhizopus nigricans*, is heterothallic and that the interaction of the two sexually opposite strains is necessary to the formation of their zygospores.

TABLE I. STRAINS IN SPONTANEOUS ZYGOSPORIC CULTURES.

Source of Zygosporic Cultures.	Substratum on Which the Zygospores Were First Discovered.	Number of Pure Cultures Tested. (—)	(+)
Boston, Mass.	Shells of almond nuts on sterilized paste.	1	29
Brookline, Mass.	Shells of almond nuts on sterilized paste.	2	6
Newton, Mass. (*a*)	Shells of almond nuts on sterilized paste.	3	18
Newton, Mass. (*a*)	Shells of almond nuts on sterilized paste.	1	1
Newton, Mass. (*b*)	Shells of almond nuts on bread.	3	18
Cambridge, Mass.	Decayed potato.	1	6
Chapel Hill, S. C.	Bread.	6	6
Stanford Univ., Cal.	Squash.	5	2
Raleigh, N. C.	Sweet potato.	19	1
8 zygosporic cultures	Totals, 107 strains.	38	69

[3] 'Beiträge zur Morphologie und Physiologie der Pilze,' II., 1866.

[4] 'Sexual Reproduction in Mucorineæ,' *Proc. Am. Acad.*, 40: 205–319, pls. 1–4. 1904.

TABLE II. INDIVIDUAL STRAINS ARRANGED ACCORDING TO SEXUAL CHARACTER.

(—)	Neutral.	(+)
Boston, Mass.	Brookline, Mass. (2)	Brookline, Mass.
Jamaica Plain, Mass. (2)	Winthrop, Mass.	Worcester, Mass.
New Haven, Conn.	Middletown, Conn.	New Haven, Conn.
Cazenovia, N. Y.	Granville, Ohio.	Storrs, Conn.
Chicago, Ills.	Breslau, Germany.	Washington, D. C.
Lansing, Mich. (2)	Leipzig, Germany.	Ithaca, N. Y.
Austin, Texas.	Halle, Germany.	Delaware, Ohio.
Columbia, South Carolina.	Honolulu, H. I.	Madison, Wisconsin.
Nassau, Bahamas.	Margarita, Venezuela. (2)	St. Louis, Mo.
Progreso, Yucatan.	Caracas, Venezuela.	Paris, France.
Cambridge, England.	Port au Prince, Haiti.	Berlin, Germany.
Paris, France.		
Nancy, France.		
Bern, Switzerland.		
Berlin, Germany.		
Eisenach, Germany.		
Manila, P. I.		

TABLE III. LIST OF SPECIES, THE THALLIC CONDITION OF WHICH HAS BEEN DETERMINED, ARRANGED ACCORDING TO THE TYPE OF THEIR SEXUAL REPRODUCTION.

Homothallic.	Heterothallic.	(—)	Neutral.	(+)
1. Sporodinia grandis.	1. Mucor Mucedo.	2	—	1
2. Spinellus fusiger.	2–7. Mucors III.–VIII.			
3–4. Mucors I and II. Heterogamic.	8. Rhizopus nigricans.	27	13	19
	9. Phycomyces nitens.	1	3	6
5. Zygorhynchus Moelleri.	10. Circinella umbellata.	2	—	2
6. Zygorhynchus heterogamus.	11. Cunninghamella echinulata.	2	—	2
7. Dicranophora.	12. Absidia caerulea.	3	2	1
	13. Absidia repens.	1	—	1
	14. Absidia sp.	1	—	1
	15. Helicostylum piriforme.	1	—	3
	16. Syncephalastrum.	2	—	1
	17. Mucor N, n. gen.	1	—	1

In Table III., which contains the species investigated by the writer, arranged according to their thallic character, the figures opposite the heterothallic forms indicate the number of different (+), (—) and neutral strains which have been tested of these species. In addition the writer has a considerable number of cultures which the hybridization reaction would indicate are unmated strains of heterothallic species.

The sexual character of individual strains of all the heterothallic species investigated has remained unaffected when they are cultivated vegetatively. Thus the (+) and (—) strains of *Phycomyces* and *Mucor Mucedo* have been cultivated separately for 92 and 90 sporangiospore generations, respectively, and are as active sexually as when their zygospores were first discovered. Moreover, the two opposite strains of *Rhizopus* have by daily transfers of mycelia been brought to the seventieth generation and by transfers of sporangiospores to the thirtieth generation without the production of zygospores; yet it is only necessary to make sowings together on the proper substratum of spores from the (+) and (—) tubes at the end of the series in order to obtain zygospores in abundance. The homothallic species have also been cultivated to many non-sexual generations, some of them for ten years and over, without change in their sexual behavior. Homothallism and heterothallism therefore seem to be fixed conditions in the forms in which the sexual character has been determined.

In view of the facts summarized, it would seem probable that Mr. Hamaker had been working with impure cultures rather than that he had discovered a new homothallic species of *Rhizopus*. This is further sug-

gested by experiments with zygosporic material which was part of a spontaneous growth on bread exposed in the laboratory of Leland Stanford University. Professor Campbell writes that he has almost always gotten zygospores in this way since 1892, yet an investigation showed that the culture contained but the two sexually opposite strains which were alone incapable of zygospore formation. *Rhizopus* shares with *Penicillium* the doubtful distinction of being the most common fungus weed in laboratory cultures, and it is almost impossible to keep a favorable substratum such as bread in a moist atmosphere for a week without obtaining an abundant growth of this characteristic 'bread mould.' When (+) and (—) spores are in the laboratory, one is very likely to get in spontaneous cultures a growth producing zygospores from the germination of sexually opposite spores which may chance to be together on the bread and, if a mixed sporangial transfer is made from a culture already producing zygospores, one is almost certain to obtain them. That spontaneous zygosporic cultures thus often occur has frequently been experimentally demonstrated by the writer in the Harvard laboratory.

The zygospore of the heterothallic species *Phycomyces,* in germinating, typically produces a sporangium containing both male and female spores.[5] If the germ tube be forced to grow into a mycelium before the differentiation of sex in the germ sporangium, a homothallic mycelium results. The condition in these homothallic mycelia is unstable and the delayed segregation of sex takes place at the formation of spores in the sporangia which they eventually produce. Until this homothallic character becomes fixed, one can not speak of a homothallic race of *Phycomyces;* but the facts already obtained are such that one would not be justified in saying that, in other heterothallic forms, homothallic races may not exist. The experiments with *Rhizopus,* however, render it extremely improbable that this species is other than strictly heterothallic. A few zygospore germinations of *Rhizopus* have been secured, but not as yet in a condition to enable one to analyze the sexual character of the germination.

Although up to the time of the discovery of heterothallism in the mucors the zygospores of *Rhizopus* are found reported in the literature but five times, they can hardly be rare. They are generally covered by the sporangial growth and, to one unfamiliar with their appearance, are distinguishable only with the aid of a microscope. The writer has found them in spontaneous bread cultures in Eisenach and Halle, Germany, and Professor Lloyd and Miss Watterson have obtained them in the same manner in Teachers College, New York.

Rhizopus is not so sensitive to the influence of external conditions in regard to the formation of its zygospores as many other of the heterothallic mucors. The ordinary substrata used in the laboratory are few upon which zygospore formation can not be induced if proper regard be had to conditions of moisture. Carbohydrates are especially favorable and bread makes an admirable culture medium. The writer has in progress a series of experiments to determine the conditions under which zygospore formation is possible in the various species. The fact that in agar cultures with 1 per cent. peptone zygospores have been obtained by the addition of varying amounts of grape sugar from 0.1 per cent. up to 40 per cent., will be sufficient to show that zygospore production in this species is not limited to any great extent by the composition of our ordinary culture media. The temperature is not a very important factor in this instance. Up to at least 27° C., an increase in temperature accelerates the growth and increases the production of zygospores. More or less moisture in the surrounding air, on the other hand, is necessary to the formation of zygospores and, as the writer has already shown (*l. c.*), their production may be suppressed before that of sporangia by sufficient desiccation.

The writer[6] has already described the

[5] 'Zygospore Germinations in the Mucorineæ,' *Annales Mycologici*, 4: 1–28, pl. 1. 1906.

[6] 'Two Conidia-bearing Fungi, *Cunninghamella* and *Thamnocephalis*,' *Bot. Gazette*, 40: 161–170, pl. 6. 1905.

method of obtaining the zygospores of *Cunninghamella* by contrasting in cultures different strains of this species. By a sufficient accumulation of material from different sources, one might expect eventually to obtain the two sexual strains and, by their synthesis, the zygospores as well of any form in which the sexes are separated on different mycelia.

Undoubtedly a careful search below the sporangial growth would show that zygospores are more common in spontaneous cultures than is usually supposed. In searching for forms of the mucors, the writer had occasion to make cultures on sterilized paste and on bread of various substances among which the shells of different kinds of nuts were thus investigated. It may not have been a mere accident that in all the several instances in which shells of almond nuts were used, zygospores were produced, but failed to appear when shells from other kinds of nuts were employed. These almond nuts were obtained from different places in the neighborhood of Boston, though they all probably came from the same source originally. The writer would be glad to learn if others have a similar experience with the shells of this species from other localities.

In making cultures, the bread should be raised above the bottom of the culture dish by some convenient object, otherwise the bread is likely to become soggy and attacked by bacteria. Layers of moistened filter paper on the sides and bottom of the dish, which should be covered, ensure a proper moist condition in the surrounding air. Those desiring to have absolutely pure cultures may first sterilize the bread dry and then allow it to soak up a sufficient amount of sterilized water to give it a spongy consistency, after which it may be sterilized with steam for about five minutes. Prolonged sterilization as well as too much water in the bread makes it soggy and less advantageous for cultures. Sterilization is not necessary, however, for class work. Zygospores when present are likely to form in dense masses between the layers of moist filter paper lining the culture dish or in the folds of crumpled pieces of filter paper placed in the culture as traps for their capture. Sporangia form where the air is dryer, and the habit of growth can be readily studied from the filter paper in the upper parts of the culture. The individual stolons can be more easily distinguished if darkened paper be employed. When zygospores are once obtained, mass transfers of the mycelium may be made to new cultures and thus the *Penicillium*, which is a usual weed in spontaneous cultures, may be eliminated. A culture producing zygospores may be dried with its substratum and used from time to time as 'seed' whenever zygospores are needed. Zygosporic cultures of the 'Harvard Strain' have thus been kept running for nearly ten years. The sporangiospores of *Rhizopus* are comparatively short lived, however, and generally do not retain their vitality for more than a year.

For methods of separating out the two sexual strains from a zygosporic culture, which is often a tedious process, one may refer to the writer's detailed experiments with this species already cited.

A. F. Blakeslee.

Halle, Germany.

RESULTS FROM MOORE'S METHOD OF SHIPPING BACTERIA ON COTTON.

In Science of March 23, Messrs. Kellerman and Beckwith have called attention to the statement in Bulletin 270 of the New York Agricultural Experiment Station that [certain[1]] 'cultures of nodule-forming bacteria dried upon cotton were worthless for practical purposes and that the failure of such cultures was inherent in the method of their preparation.' At the same time they presented some excellent data upon the effect of drying legume bacteria under various conditions. Their most interesting experiment consisted in placing a culture "on cotton half of which was placed in a sterile Petri dish, to make drying very slow, half was dried rapidly and kept

[1] An important word omitted by Messrs. Kellerman and Beckwith in summarizing the statements contained in Bulletin 270.

over calcium chloride. After 25 days the cotton in the Petri dish was sterile; the cotton from the desiccator was a pure culture in good condition, containing numberless organisms." They also found that cultures properly dried and then exposed to moist air died within a few days.

The experiment with cotton in the Petri dish was evidently intended as a repetition of similar experiments given in Bulletin 270 in which inoculated cotton placed in Petri dishes became practically sterile within a few days. The analytical results obtained at the two laboratories were practically identical and it may now be considered fairly established that legume bacteria placed upon cotton according to Moore's method do not survive slow drying. The exact limits of the exposure which they will survive remains to be established.

It should be kept in mind that the present discussion is restricted to certain packages of inoculated cotton which were offered to the public last season and to the methods by which these packages were produced. The point which should be made clear is which of the portions of cotton in the experiment of Messrs. Kellerman and Beckwith most nearly represents these packages. The eighteen cultures discussed in Bulletin 270 were purchased in the market and were the product of a single commercial laboratory. They were repeatedly examined, six of them being tested in each of five different laboratories, and were found to contain extremely few or no living specimens of the desired germ. Their worthlessness for practical purposes was accordingly settled beyond question. Eight other packages of inoculated cotton put up by the same firm but obtained through other channels were examined with similar results.

The method of preparation of these cultures, as stated by the manager of the company to the writer, was to dip the rolls of absorbent cotton into the culture fluid and suspend them in a room until air dry. The cotton was then cut into squares and shipped in pasteboard boxes. Judging from the fact that the germs were practically all dead in the packages examined by us, either the cotton dried slowly or the germs were killed by being exposed to moist air. The chemicals accompanying the cultures uniformly showed the presence of absorbed moisture.

Since this commercial method of preparing cultures included both slow drying and shipment in a package which exposed the cotton to moist air and the germs were actually killed by this treatment, it is plain that it is the cotton in the Petri dish in the experiments by Kellerman and Beckwith which fairly represents the commercial packages.

A careful study of the facts leads to the conclusion that the criticisms justified by our results with commercial cultures are equally applicable to the methods of the Bureau of Plant Industry up to the season of 1905 at least. Until a few months since, the member of the Bureau of Plant Industry then in charge of the legume-bacteria investigation was also in close touch with this commercial company. It was accordingly to be expected that the methods employed in both laboratories would be practically identical and any important criticism against the methods employed in, or the product of, one laboratory would apply to the other. For this reason an examination of the methods employed, and the packages of inoculated cotton put out, by the Bureau of Plant Industry during the past two seasons is both interesting and instructive.

The earliest official description of the bureau's method of preparing the cultures on cotton is given in Letters Patent No. 755,519, dated March 22, 1904, and signed by G. T. Moore. These state that 'absorbent cotton or other equivalent material is dipped into the water containing the organisms or the water containing the organisms is sprinkled upon the cotton or other material and the same thoroughly air dried in a chamber free from dust or contamination by mold.' A more recent and detailed description of the method is given by L. P. Sprague in a thesis presented to the faculty of the University of Vermont on 'The Fixation of Nitrogen by Leguminous Plants,' dated May 1, 1905. Mr. Sprague served as an assistant to Dr. Moore in the Bureau of Plant Industry and gives the following detailed description of the method there employed. "Absorbent cotton of the

best grade, which has been sterilized by heating, without unrolling, in the dry oven about four hours at 150° C., is unrolled and placed in a tin pail, the pail having been sterilized by rinsing in boiling water, and the culture poured over it. The cotton is thoroughly saturated with the culture solution, by pressing and squeezing it with the hands. It is then hung up in the culture room, where it is nearly free from foreign organisms, and allowed to dry, *drying taking place in twenty-four to forty-eight hours*. It is then stored in pasteboard boxes in the laboratory until ready for use. Other methods for inoculating and drying have been attempted, but thus far they have been unsuccessful."

In a recent repetition of our experiments in Petri dishes as detailed in Bulletin 270 it was found that the inoculated cotton under such circumstances becomes air dry in approximately twenty-four hours. Accordingly it is seen that the method of preparation employed by the Bureau of Plant Industry not only is practically identical with that employed by the commercial company above described, but also the rate of drying is practically the same as that in our Petri dish experiments in which the germs placed upon the cotton died promptly.

Our own examinations of the bureau cotton is limited to six packages. While the number of packages is small, it is significant that from none of these packages did we succeed in isolating a single specimen of *P. radicicola* although some of the packages were repeatedly examined. Similar laboratory tests of a number of packages of bureau cotton were made at the agricultural experiment stations in Delaware and North Carolina with similar negative results. The results of pot and field tests at the agricultural experiment stations in Pennsylvania, Oklahoma, Georgia, Maine, New York (Cornell) and Wisconsin as published fail to show any well-marked results from the use of inoculated cotton furnished by the bureau. Two other stations, Michigan and Virginia, have kindly furnished us with a summary of like unpublished tests which are also negative.

Although such may exist it is a surprising fact that thus far we have not learned of a single experiment conducted at one of the many state agricultural experiment stations where the inoculated cotton put out by the Bureau of Plant Industry has given good results.

The marked exception to this wide record of failure is furnished by Bulletin 71, Bureau of Plant Industry. When considering the favorable reports there presented we are forced to conclude that an explanation is to be looked for largely in the psychological, rather than in the biological, realm.

When we consider the methods of preparation, storage and shipment employed by the Bureau of Plant Industry as described by Sprague in connection with the data upon the effect of slow drying and moist air as given by Messrs. Kellerman and Beckwith, an utter failure of the bureau's cultures was the only result which could be logically expected.

H. A. Harding.

New York Agricultural Experiment Station, May 2, 1906.

QUOTATIONS.

ZOOLOGICAL GARDENS AND SCIENTIFIC RESEARCH.

Dr. Gustav Loisel, who is a professor of zoology in the Sorbonne, is making persistent efforts to have the menagerie in the Jardin des Plantes adapted to the needs of experimental science. He would have it so transformed as to become a school of zoological research without at the same time ceasing to be a place of entertainment for the people. Such a plan has been partly carried out in Bronx Park, so that certain fauna are permitted to live and breed almost as if they were in 'the wild.' The experimental stations in this country where marine animals and plants may be studied have proved of the highest value to science; and the laboratory in connection with the Naples Aquarium has long been a favorite resort for naturalists. Two of Dr. Loisel's suggestions are not likely to meet with popular approval. One is to do away altogether with the monkey house, which he says is infected with tuberculosis, and the other is to diminish the number of the more formidable wild animals to make room for beasts whose habits

may be more conveniently studied. But in general there is no good reason why the zoological collections of the world should not be adapted to the needs of students of natural history who should have advantages analogous to those already enjoyed by workers in botany and in the fine arts.—*The N. Y. Evening Post.*

THE WILL OF ALFRED BEIT.

THE public bequests made by Alfred Beit, who died on July 16, were made public in London on July 20, and have been cabled to this country.

The most notable bequest is $6,000,000 to his partners to constitute a fund, the income of which is to be devoted to the construction, equipment or furtherance of any such methods of communication or transportation in Rhodesia, Portuguese Southeast Africa or the German possessions, and any parts of Africa that may be traversed by the Cape-to-Cairo Railway. The trustees are to have absolute discretion, and if two thirds decide that the fund is no longer required for furthering the work of communication or transportation, they can apply the proceeds to educational, charitable or other public purposes in Rhodesia.

One million dollars is left to the University of Johannesburg to build and equip buildings on the land previously given by Mr. Beit; one million dollars for educational or charitable purposes in Rhodesia and other territories within the field of the British South Africa Company; $125,000 to the Rhodes University, Grahamstown, Cape Colony; $100,000 for educational or charitable purposes in the Transvaal, and $75,000 for similar purposes in Kimberley and in Cape Colony.

To the College of Technology, London University, the sum of $250,000 and 1,000 shares in the DeBeers Company are bequeathed, and to the research fund of London University $125,000.

Two hundred thousand dollars is to be distributed equally in London and Hamburg for educational or charitable purposes. To King's Hospital and Guy's Hospital, London, the sum of $100,000 each is given. Mr. Beit's property near Hamburg, which was his birthplace, is left to that city, and his art collections are left to the galleries in London, Berlin and Hamburg.

SCIENTIFIC NOTES AND NEWS.

THE Lavoisier medal of the Chemical Society of Paris and the Hofmann medal of the German Chemical Society are to be presented to Dr. W. H. Perkin, on the occasion of the celebration this week of the jubilee of the coal-tar industry.

THE eightieth birthday of Dr. Georg von Neumayer, late director of the Deutsche Seewarte, which occurred on June 21, was celebrated at Neustadt, where he now lives. An address was presented by Dr. S. Günther, of Munich. It is proposed to establish a foundation for the encouragement of research by geographical students, and arrangements may be made for the painting of a portrait of Dr. Neumayer, to be placed in the Historical Museum at Speier.

Professor Carl Vogel, director of the Astrophysical Observatory at Potsdam, has been elected a correspondent of the Paris Academy of Sciences, in succession to the late Dr. S. P. Langley.

PROFESSOR JULIUS FRANZ, director of the Breslau Observatory, has been elected an associate of the Royal Astronomical Society.

DR. EMIL FISCHER, professor of chemistry at Berlin; Dr. Stanislao Canizzaro, professor of chemistry at Rome, and Dr. Daniel Oliver, lately keeper of the herbarium of the Royal Botanical Gardens, Kew, have been elected foreign members of the Royal Society of New South Wales.

A NUMBER of foreign scholars and men of science have been invited to take part in the opening of the main building of the Carnegie Institute, Pittsburg, in April next. Among those who have accepted are Sir William Huggins and Sir William Preece.

MR. S. F. EMMONS, geologist of the U. S. Geological Survey, in charge of the section of metalliferous deposits, will personally supervise investigations made this summer by members of the survey in various mining re-

gions in the west. He will visit Butte, Mont., and adjoining districts, Ely, Nev., and other camps.

Geologic surveys in the crystalline rocks of northern New Jersey will be carried on this summer by Mr. W. S. Bayley of the U. S. Geological Survey. This work will extend into the Greenwood Lake and Ramapo quadrangles. When it is completed, the entire state of New Jersey will have been surveyed.

The granite deposits and granite quarrying industry of New England will be investigated this summer by Mr. T. Nelson Dale, geologist of the U. S. Geological Survey.

Mr. Homer R. Dill, Gardiner, Me., the state taxidermist, has been appointed chief taxidermist in the new Museum of Natural History of the Iowa State University.

Professor Uhlenhuth, of Greifswald, has been appointed director of the newly-established bacteriological department of the Imperial Bureau of Health, Berlin.

Dr. H. Rosenbusch, professor of mineralogy and geology at Heidelberg, celebrated, on June 24, his seventieth birthday.

The Mackinnon studentships for the year 1906–1907 have been awarded by the Royal Society to Mr. W. G. Duffield, 'for the study of arc spectra of metals under high pressures'; and to Dr. F. H. Scott, 'for the continuation of studies on the nature of the process of excitation of nerve cells.'

Dr. J. Bishop Tingle, assistant in organic chemistry at the Johns Hopkins University, has received a grant from the C. M. Warren fund of the American Academy of Arts and Sciences, to aid in the purchase of chemicals for use in continuation of his investigations of certain derivatives of camphor-oxalic acid.

The Prussian Academy of Sciences has made a grant of 5,000 Marks to Dr. F. Mertens, professor of mathematics at Vienna.

Sir Daniel Morris, commissioner of agriculture for the West Indies, delivered a lecture at the West India Committee Rooms on July 19, on 'The Present Position and Prospects of the Sea-Island Cotton Industry.'

The following popular lectures have been arranged by the Royal Society of New South Wales:

June 21.—'Some Results of Archeological Work in Jerusalem,' by Professor Anderson Stuart, M.D., LL.D.

July 19.—'Our Water Supply from Source to Distribution,' by J. M. Smail, M.Inst.C.E., engineer-in-chief, board of water supply and sewerage, and E. S. Stokes, M.B., D.P.H., medical officer, board of water supply and sewage.

August 16.—"Sir Joseph Banks, the 'Father of Australia,'" by J. H. Maiden, F.L.S., director, Botanic Gardens.

September 20.—'Recent Developments in Long Distance Electrical Transmission,' by T. Rooke, Assoc.M.Inst.C.E., city electrical engineer.

November 15.—'Chapters in Early Australian History,' by F. M. Bladen, F.R.G.S., F.R.H.S. (Lond.).

Nature states that a special meeting was held in the Great Hall of the University of Athens on May 20 to celebrate the fortieth anniversary of Dr. A. C. Christomanos's appointment as professor of chemistry in the university. A large audience, including the Greek minister of education, the university professors and students and many of the general public, was present. Dr. A. C. Dambergis, the professor of pharmaceutical chemistry, referring to the great work which Professor Christomanos has done in the forty years, asserted that the greatest has been the pioneer work in the introduction of scientific chemistry into Greece with the provision for laboratory work in chemistry and the other sciences, and more particularly in organizing so successfully the large chemical department of the university with its laboratory accommodation for 130 students. Professor Christomanos was the recipient of numerous honors, including several from foreign countries.

The students and friends of the late Professor A. Kekulé, the eminent chemist, have contributed about $8,000 to establish a scholarship at the University of Bonn in his memory.

The death is announced of the Rev. John Frederick Blake, formerly professor of natural science in University College, Nottingham, and at one time president of the Geological Association.

DR. A. HÖRMANN, professor in the Technical Institute at Charlottenburg, died on June 30, at the age of seventy-one years.

JUDGE EDOUARD PIETTE, noted for his writings on prehistoric archeology, died at the Château de la Cour des Prés, Rumigny, Ardennes, on June 5, in his eightieth year. Some years ago he gave his valuable collection, chiefly from the caverns of southern France, to the Museum of National Antiquities at St. Germain-en-Laye, near Paris.

THERE will be on August 8 an examination for the position of fish culturist in the Bureau of Fisheries at salaries ranging from $540 to $900.

THE *Experiment Station Record* states that lands have been set aside at Hamakua, Hawaii, for a tobacco farm. Experiments to cover three years are planned, which will be carried out under the direction of the Federal station. The funds for carrying on the farm are to be supplied by private parties.

As a result of the passage of the bill allowing the sale of alcohol without the internal revenue tax, the Department of Agriculture has decided to publish a bulletin on the first of January, 1907, when this law goes into effect, giving the public a collection of the best obtainable data on the use of alcohol in small engines. For this purpose Professor Charles E. Lucke, of Columbia University, has been retained by the department as expert to conduct these investigations in the laboratories of the university. This bulletin will contain all the work done on the subject, both here and abroad, a complete bibliography, together with the results of experiments and the conclusions drawn therefrom on American engines. Those who have patents on the subject or vaporizers, carburettors or complete engines are invited to submit them for tests. These tests will be conducted without expense, except the transportation of the apparatus, and the reports will be published in the bulletin.

THE French government has undertaken to publish the results of Dr. Jean Charcot's antarctic expedition. The Naval Department is to publish the following: (1) Narrative of the voyage; (2) hydrographical results, comprising nautical instructions, description, with views and photographs, of the coasts surveyed, maps and charts; (3) astronomical observations; (4) observations on terrestrial gravity; (5) analyses of samples of sea-water; (6) meteorology; (7) terrestrial magnetism; (8) atmospheric electricity; (9) medical report. Further, the Department for Public Instruction is to guarantee the publication of reports on the geology, glaciology, zoology, bacteriology and botany of the expedition. The two parts will constitute one work, which will be entitled 'The Cape Horn Scientific Mission.'

DR. JOSEPH W. RICHARDS, of Lehigh University, is making an extended journey through central Mexico and will later attend the International Geological Congress.

WE learn from *Nature* that arrangements have been completed for the erection of a commodious laboratory for the study of marine biology at Cullercoats, on the Northumberland coast. A much smaller laboratory, which had been provided by Alderman Dent, the chairman of the County Council's fisheries committee, was accidentally burnt down some few years ago, and the proposed building is designed to carry out, not only fishery research, but also general biological studies. The gift of the site and the cost of erection of the building will be borne by Mr. Wilfrid Hudleston, F.R.S., the management being under the control of the Armstrong College at Newcastle.

The British Medical Journal states that the University of Vienna has delegated several of its geologists, together with two professors of chemistry, to join a body of men of science now at work at Carlsbad, to devise means for securing the springs against telluric and seismic disturbances. Once previously, in 1775, when the great earthquake in Lisbon occurred, the waters disappeared for three days, only to return turbid and changed in taste and temperature. But these changes soon passed off.

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ALL-YEAR-ROUND investigation of problems in fresh-water biology is made possible by a recent provision for a division of limnology in the department of invertebrate zoology in

Cornell University. Dr. James G. Needham, of Lake Forest College, has been appointed assistant professor of limnology to take charge of that work. He will enter upon his duties at Ithaca in February, 1907. A site for a biological field station has just been selected on the Renwick Lagoon at the head of Cayuga Lake. It is accessibly located at the end of a street-car line a mile from the university; it is surrounded by a rich fauna and flora, and is well adapted to the investigations to be undertaken there. The necessary station building and equipment will be provided in the spring. In the future a general course in limnology will be offered in the university, and provision will be made for research students from the beginning.

The council of the Medical Alumni Association of the Harvard Medical School has issued an appeal to the twenty-nine hundred living graduates for subscriptions to increase the salaries of instructors and assistants.

Mr. S. F. Leib, president of the Board of Trustees of Stanford University, and Dr. David Starr Jordan, president of the university, have made public the following notice, under date of July 12: "We desire to inform the students, alumni and friends of Stanford University that the work of the university will continue as usual in all departments for the coming term. The buildings of the inner quadrangle were scarcely injured by the disaster of April. The work of restoration of the outer quadrangle is being pushed as rapidly as possible, and we feel certain that the buildings necessary for the actual work of the university, such as class-rooms, libraries, laboratories and dormitories, will be ready for use by August 23, the date of the entrance examinations for the new term, the registration of students beginning on August 28, and instruction on August 30."

Further details are now announced of the visit of English school teachers to the United States, arranged by Mr. Alfred Mosely. Five parties, each containing one hundred teachers, will come to this country, beginning in November next. They will be given leave of absence with salary by the school, and the steamship companies will give them return transportation for $25. It is expected that reduced rates will also be secured from American railways and hotels. Each party will visit the schools of New York City, and of some section of the country. The parties will be only twelve days each in the United States.

Dr. G. D. Harris, of Cornell University, has been elected to the chair of geology in the Louisiana State University, and will divide his time between university duties and the direction of the geological survey of Louisiana.

Raymond Longley, Ph.D. (Chicago), has been appointed instructor in mathematics and astronomy at Yale University.

At Tulane University, Professor Henry F. Rugan has been advanced to be associate professor of mechanic arts and Dr. Joseph Ivey to be associate professor of mathematics and astronomy.

Professor W. A. Stocking, Jr., has been appointed assistant professor of dairy bacteriology in the State College of Agriculture at Cornell University. Professor Stocking has been connected with the Connecticut Agricultural College and Experiment Station the past few years.

At New Hampshire College, Instructor Charles Brooks has been made associate professor of botany. Mr. F. W. Putnam (Worcester, '99) has been made assistant professor of drawing and T. J. Headlee, Ph.D. (Indiana, '06), assistant entomologist. In the chemical department Mr. Charles James, who obtained his training with Sir William Ramsay, has been appointed instructor.

Mr. Paul Langer, of Milwaukee, has been elected acting professor in the technical institute at Aachen.

The Experiment Station Record states that a chair of fishery and fish breeding has been established at the Agricultural High School of Berlin and will be occupied by Dr. P. Schiemenz, director of the Müggelsee Biological Station, which now becomes a department of the Agricultural High School.